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Emerging symbiosis: Renewable energy and energy security

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ABSTRACT

This article reviews the evolution of "energy security" as a concept guiding strategic energy planning and demonstrates how fossil fuel technologies which once enjoyed a symbiotic relationship with energy security no longer contribute to the goals of enhanced energy security. Conversely, renewable energy technologies now fulfill many of the objectives that modern energy security enhancement initiatives aim to achieve. The article concludes that the existing fragmented structure of the renewable energy technology sector places the sector at a financial disadvantage when trying to break the technological lock that fossil fuel technologies have on energy provision and argues for a unified effort aimed at fostering improved public understanding of alternative technology capabilities and mustering political support for a transition away from fossil fuel technologies. Failure to unify may lead to nuclear power or fossil fuel combustion and carbon capture and sequestration becoming entrenched as the preferred near-term approach to CO_2 abatement.

Contents

1. Introduction

Symbiosis describes a relationship between two biotic elements (flora or fauna) that is positive for both parties. A famous example of symbiosis involves the Egyptian plover which acquires food by picking the teeth of the Nile crocodile, while the crocodile in turn, receives free dental service [1].

This paper critically examines the concept of energy security and demonstrates how climate change and the drawdown of fossil fuel energy supplies has turned the once symbiotic relationship between energy security and conventional fossil fuel energy technologies into to a parasitic relationship wherein continued reliance on conventional energy technologies adversely affects energy security. The paper then examines why nuclear power does not represent a suitable substitute for fossil fuels in terms of delivering enhanced energy security and goes on to demonstrate how renewable technologies provide enhanced energy security now and in the foreseeable future. Renewable energy and energy security represent the new symbiosis.

2. Energy security: a historical perspective

In order to understand how energy security is conceptualized today, it is insightful to examine how the concept evolved because

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remnants from past perspectives tend to have a "sticky" influence on technologically dominant regimes [2].

Energy security is conceptually as old as fire which was purportedly well-entrenched by the Lower Paleolithic Period (the Early Stone Age) which ended 200,000 years ago [3]. Musing over those early days it is not difficult to imagine what energy security meant to early human civilizations. Settlements enjoying high levels of energy security would have been characterized by access to adequate supplies of flammable material (i.e. wood) that could be procured without incurring excessive safety risks or without requiring more effort to procure than the fire was valued at. As knowledge spread regarding the value of fire, it is highly probable that a new energy security criterion would have emerged, the capacity to prevent marauders from pillaging the supplies. So here we have the foundations of the concept we know today as energy security that over 200,000 years ago incorporated three criteria: (i) availability of sufficient supply to meet demand, (ii) affordability in which the opportunity cost of procuring fuel stock was not greater than the perceived value of the fire and (iii) resilience, the capacity to ensure the supply of fuel stock would not be disrupted by external events.

Through to the 1950s, criteria for evaluating energy security had not substantively changed from Lower Paleolithic times. Availability, affordability and resilience continued to be the dominant objectives for enhancing energy security. However, what did change were the strategies for achieving these objectives. The concept of availability broadened through technical innovations to accommodate a number of different sources of fuel (i.e. hydro, nuclear, fossil fuels etc.) procured both domestically and internationally. The concept of affordability took on temporal (i.e. short versus long-term) and political dimensions (i.e. employment) as well as systematic dimensions (i.e. base-load versus peak-load technologies). The concept of resilience was conceptually extended through military experiences to include not only preservation of existing energy reserves but also the fortification of energy networks against external disruptions [4]. In short, although strategies for enhancing energy security increased as technology, geopolitics and economic sophistication intensified, for over 200,000 years, the basic paradigm for energy security remained unchallenged.

This enduring perspective on energy security began to show increasing signs of transformation after WW2. With the exception of hydropower, fossil fuels had achieved a virtual global lock on energy; and the seemingly insatiable demand for energy in many nations produced a number of high profile environmental catastrophes – such as the coal combustion-related deaths in Donora Pennsylvania in 1948 and London's killer smog in 1952 – which raised public ire [5,6]. Concerns over adverse health impacts and ecological damage associated with particulate matter, sulphur dioxide and nitrous oxide led to a number of anti-pollution regulations such as the US Clean Air Act of 1963 and its subsequent amendments which introduced standards to regulate vehicle emissions and the combustion of high sulphur coal. The Act also established funding for emission abatement research.[1] Although it can be argued that the ineffectual nature of early air pollution legislation is what necessitated ongoing regulatory revisions, when viewed with the benefit of hindsight, the gradual fortification of emission standards and the influence that such legislation had on energy planning impacted energy security ideology in an unprecedented manner.

Fortunately for the entrenched fossil fuel regime, technological solutions attenuated much of the consternation over air pollution associated with fossil fuel combustion [6] and these technological fixes seemed to prevent environmental concerns from ascending to a position of equitable importance in energy security planning. By the end of the 1980s, with the exception of a small core of scientists studying the impact of CO_2 on the global climate, air pollution associated with fossil fuel combustion appeared to be on the path to resolution.

3. Winds of change

Scientific confirmation that CO_2 emissions associated with fossil fuel energy combustion represent the largest source of greenhouse gas emissions from human activity has effectively reversed the wane of concerns associated with pollution from fossil fuel combustion [7,8]. It is becoming increasingly evident that the level of CO_2 emissions associated with fossil fuel combustion is so voluminous that an effective technical fix to the problem is dubious [9–12]. In short, the challenge of reducing CO_2 emissions to abate climate change impacts will likely require a different response than the pollution abatement technologies of the past represented. For the first time in over 200,000 years of human energy consumption, humanity is now faced with an environmental constraint on fossil fuel energy growth and severe economic penalties for continuing to exceed atmospheric assimilative capacity [13]. Climate change represents the first salvo in what appears to be an intensifying assault on the validity of the dominant paradigm that embraces fossil fuel energy as the synergic partner for enhancing energy security.

As Thomas Kuhn cautioned, for an existing paradigm to be replaced by a new paradigm, there must be overwhelming evidence that the new paradigm is a better "puzzle solver" [14]. The trouble is that vested-interests associated with the existing technological regime continue to sow seeds of optimism that somehow a technological solution in the form of carbon capture and sequestration can be devised to abate CO_2 emissions in the same way that technological fixes were devised in the past to abate sulphur dioxide, nitric oxide and particulate matter emissions [15,16]. Meanwhile, the contesting regime represented by renewable energy technologies is impugned by some as being incapable of providing sufficient energy in a reliable manner at affordable prices [9,10,17–19].

Simply put, while the evidence is overwhelming to some that renewable energy represents a more secure energy future [17,20–22], there are documented cases of others in power who contest such claims [15,23–25]. Barring any developments which alter how nations view energy security, a rational review of the global energy outlook would have to conclude that although there are increasing signs of progress in transitioning away from carbon-intensive energy technologies, the ascendency of renewable energy technologies to global dominance will be slow in materializing (if at all) unless the renewable energy regime can categorically prove that it offers a superior solution to nuclear power or fossil fuel energy generation twinned with carbon capture and sequestration.

Providentially, there are emergent developments that may indeed add air to the sails of technological transition. Across all criteria, the symbiotic relationship between energy security requirements and fossil fuel energy is showing signs of corrosion.

3.1. Challenges to availability

All fossil fuels are finite resources. Historically, this has never been a problem for humanity because the vast abundance of fossil fuel reserves rendered the perils of supply constraints to be a distant concern. However, consider the following current assessments. Regarding coal, from 2000 to 2005, the world's proven reserves-to-production ratio purportedly plummeted by over 40%, from 277 to 155 years [26]. Concerning oil, the Japanese government which oversees an oil dependent economy estimates that commercially

[1] A summary of US clean air legislation is available on the American Meteorological Society's website: http://www.ametsoc.org/sloan/cleanair/cleanairlegisl.html.

recoverable reserves of oil will be exhausted in 40 years [27]. In terms of natural gas, the global reserves-to-production ratio of natural gas has been estimated at 63–66 years [27,28]. In other words, many young people alive today might actually witness the depletion of these vital resources.

3.2. Challenges to affordability

For the past decade, fossil fuel costs have been escalating in a volatile manner. The cost of North Appalachia coal swelled from a trading range of US$40–45 per short ton between December 2005 and December 2007, to US$150 per short ton in September 2008. Although, the cost retreated to approximately US$60 per ton in response to the autumn 2008 global economic slowdown which quashed demand for coal, the cost is still higher than historic levels (US$70 as of January 7, 2011).[2]

Throughout the 20th century, the price of oil averaged US$25 per barrel with major price fluctuations occurring only during times of major global economic disruption.[3] However, since the mid-1990s, oil prices have sharply escalated, topping US$140 per barrel in July 2008. OPEC estimates that the price of oil over the next two decades will range between US$70 and 100 per barrel, 3–4 times the price average recorded in the late 20th century [29]. As of December 2010, the US Department of Energy projects the cost of oil in 2035 will progressively escalate from the US$70-100 per barrel range to US$135 per barrel.[4]

Over the next six years, the market for liquefied natural gas (LNG) is expected to double [30]. The EIA anticipates that by 2030, 35% of the world's total natural gas consumption will be consumed in electricity generation [28]. Although history has demonstrated that higher prices tend to foster enhanced exploration efforts which in turn lead to expanded fossil fuel reserves, most experts project that explosive demand for natural gas will significantly outpace the expansion of supply [28,31]. In short, like the prices of coal and oil, a progressive escalation in the price of natural gas is likely.

Perhaps the most disturbing facet of these trends is the realization that for the first time in human history, the prices of fossil fuels are being predominantly driven by demand-side pressures not by supply-side manipulations [30]. Fossil fuel prices are no longer controllable through production cartels.

The one competitive advantage that fossil fuel energy providers have been traditionally able to rely on to attenuate challenges by renewable energy providers has been the comparative cost advantage of fossil fuel energy. This advantage is now under siege. Depending on the characteristics of a given energy project, it is not necessarily assured that fossil fuel energy projects will be financially superior to renewable energy projects [32–34]. For example, Sovacool [35] summarises research in the United States that contends that power from wind, hydro and landfill gas are economically superior when electricity generation costs are "levelized" to include all current capital costs, future fuel costs, future operation costs, maintenance costs and decommissioning costs (see Table 1; middle column).

The perils attributed to climate change add an additional economic burden to the demand-driven amplification of fossil fuel costs. As many climate change experts point out, the costs associated with climate change will be extensive. Some researchers contend that global economic losses alone could be as high as 4–20% of global GDP, while the World Bank estimates global adaptation costs at US$75–$100 billion per year between 2010 and 2050 [11,13,36,37]. On the ecological front, according to the IPCC, even achieving the widely embraced warming target of 2 °C would result in species extinctions of up to 30% [8]. It is for this reason that Sovacool [35] contends that when environmental externalities (such as contribution to global warming and damages from emitted pollutants) are internalized into the cost of electricity generation across the technological platforms, all mainstream renewable technologies except solar PV are economically superior to nuclear power or any fossil fuel technology (see Table 1; right column).

Table 1
Levelized Cost of Electricity (LCOE) for the United States.

Technology	LCOE (before internalizing externalities) US ¢/kWh ($2007)	LCOE (after internalizing externalities) US ¢/kWh ($2007)
Offshore wind	2.6	3.0
Onshore wind	5.6	6.0
Geothermal	6.4	7.1
Hydroelectric	2.8	7.8
Landfill Gas	4.1	10.8
Biomass (combustion)	6.9	13.6
Advanced Nuclear	4.9	16.0
Advanced Gas and Oil Combined Cycle (AGOCC)	8.2	20.2
AGOCC with Carbon Capture	12.8	24.8
Integrated Gasification Combined Cycle (IGCC)	6.7	25.9
Scrubbed Coal	7.2	26.3
IGCC with carbon capture	8.8	27.9
Solar photovoltaic	39.0	39.9

Source: Sovacool, 2008.

3.3. Challenges to resilience

The resilience of fossil fuels in terms of portability and storability has come into question in recent decades. Examples from the United States epitomize experiences shared around the world. High profile oil spills such as the Deepwater Horizon disaster in the Gulf of Mexico in 2010 and the Exxon Valdex accident in Alaska in 1989 have raised public and political awareness that extraction, transport and storage of oil can come at a steep price. In December 2008, a coal ash spill in eastern Tennessee dumped over 5.4 million cubic yards of fly ash containing arsenic, cadmium, chromium, copper, lead, mercury, selenium and other hazardous substances into the Emory River.[5] Due to the magnitude of the spill, it was dubbed the Exxon Valdex of coal ash spills [38]. In the past few months, attention has been drawn to the aging natural gas infrastructure in the US in the wake of natural gas explosions that claimed lives in Pennsylvania, California, and Texas.[6]

An additional emerging challenge to the resilience of fossil fuel technologies has been concern over how profits from fossil fuel purchases are being used [39]. There is significant support for the contention that profits from fossil fuel sales represents a key source of financing for terrorist groups [20,40,41]. Many international security analysts would agree that diverting oil profits away from unstable political regimes might not lead to a decline in the number of terrorists in the world, but it would lead to a decreased

[2] Data on coal prices between 2007 and present can be found on the Energy Information Administration web-site: http://www.eia.doe.gov/cneaf/coal/page/coalnews/coalmar.html, Accessed on January 11, 2011.

[3] Source: WTRG Economics web-site: "Oil Price History and Analysis" Accessed on June 27, 2008 at http://www.wtrg.com/prices.htm.

[4] An overview of cost projections by the US Energy Information Administration can be http://www.eia.gov/forecasts/aeo/early_prices.cfm.

[5] Source: US Environmental Protection Agency web-site. Accessed April 4, 2011 at http://www.epa.gov/region4/kingston/index.html.

[6] Source: MSNBC. Accessed April 4, 2011 at http://www.msnbc.msn.com/id/41503700/ns/us_news-life/. Additional background reading is available at http://cleanwaternotdirtydrilling.org/blog/140-recent-gas-explosions-raise-questions-of-us-pipeline-safety.

capacity for rogue nations to entrench abuses of power and finance terrorist activity.

4. Nuclear power and energy security

Prior to the nuclear disaster stemming from the earthquake and tsunami in Japan on March 11, 2011, nuclear power was championed by many energy experts as a necessary component in any climate change mitigation strategy [9,42–45]. Indeed, over 60 nations which currently do not have nuclear power facilities have recently expressed intent to the International Atomic Energy Commission to pursue nuclear power development [46]. Therefore, there is reason to believe that nuclear power may be viewed as a competitor to renewable energy technologies when it comes to enhancing energy security. However, closer analyses of nuclear power in terms of the three criteria of energy security (accessibility, affordability and resilience) demonstrate that nuclear power is a far less attractive electricity alternative than renewable energy technologies.

In terms of accessibility, the pro-nuclear Federation of Electric Power Companies of Japan concedes that there are 85 years of commercially viable uranium stores left on the planet. This gibes with an estimate from the World Nuclear Association of 80 years at current usage rates (assuming no improvement in technology).[7] Although an argument can be made that technological advancements will significantly improve utilization rates and extend the availability of uranium supplies, a counter-argument can be made that enhanced demand will likely offset improved resource utilization rates. However, despite concerns over the mid to long term availability of uranium (and possibly thorium), it should be conceded that supplies of uranium are currently more accessible than many fossil fuel supplies because uranium is located in more stable nations. Nearly half of the world's known recoverable uranium resources are found in Australia (31%), Canada (9%) and the US (5%).[8] Consequently, nuclear power tends to be seen as a technology to enhance short-term energy security in nations that are reliant on fossil fuel resources [23,24]. However, overall, resource limitations render nuclear power an unsuitable mid to long-term solution for enhancing energy security.

In terms of affordability, Table 1 presented earlier places nuclear power into proper perspective. When all current capital costs, future fuel costs, future operation costs, maintenance costs and decommissioning costs are incorporated into an economic analysis, there is evidence that advanced nuclear power is cheaper than all fossil fuel sources but more expensive than wind, geothermal and hydro power (Table 1; middle column). When environmental externalities are incorporated into the economic analysis, Sovacool's Table 1 indicates that nuclear power is still less expensive than the fossil fuel technologies but more expensive than electricity from wind, geothermal, hydro, landfill gas and biomass power technologies [35]. Moreover, it should be noted that these cost estimates were conducted before the nuclear problems in Fukushima, Japan; and as a result, they likely represent very conservative cost estimates for nuclear power when environmental costs are internalized into generation costs.

Finally, in regard to addressing the third energy security criterion–resilience–nuclear power technology underperforms even in comparison to conventional fossil fuel technologies. Although, oil profits have been linked to terrorist financing, one of the fears concerning well-financed terrorist groups is that such groups might get their hands on nuclear materials to make weapons of mass destruction [39]. Consequently, transporting and storing nuclear materials associated with nuclear power programs represent a national security threat. Furthermore, the storage of spent radioactive materials represents both a potential public safety hazard (as evidenced by the fire which broke out in the storage pond on the number 4 reactor in Fukushima, Japan) and a further threat to domestic security. Finally, the operation of nuclear plants is fraught with so much potential for inherent disaster that the threat to economic viability in the face of a major mishap (as evidenced in Japan) renders nuclear power to be a highly non-resilient technology.

In summary, although nuclear power is more attractive than fossil fuel technologies in terms of current accessibility (supplies located in more stable nations) and affordability, it is less attractive than many mainstream renewable technologies in terms of levelized costs, long-term accessibility, and resilience. Overall, the inherent dangers associated with transporting uranium, nuclear power plant operation and nuclear waste storage represent the gravest challenges to energy security and render the technology far inferior to renewable energy technologies in terms of enhancing energy security.

5. The new symbiosis

In direct contrast to fossil fuel technologies (and nuclear power) which no longer provide the benefits typically sought in regard to enhanced energy security, renewable technologies display synergic properties. As this section demonstrates, the trade-off between enhanced energy security and greenhouse gas abatement, which some proponents argued existed, no longer exists [47].

5.1. Enhancing availability

The most secure way to minimize energy supply risk is to maximize domestically controllable energy supplies [20]. Under a fossil fuel dominated energy regime, countries which are rich in fossil fuel resources are decidedly more secure. This sires "have and have not" nations which in turn fosters political tension around the world [48,49]. The cost of ensuring access to imported energy supplies comes at a cost that is rarely factored into fuel prices but nevertheless evident. For example, Stern [50] estimates that the cost of US military activities in the gulf region which have been attributed to ensuring access to oil [20] amounted to US$6.8 trillion between 1976 and 2007 and a further US$500 billion in 2008 alone. Conversely, consider an electricity regime dominated by wind power, solar power and hydropower. These all represent technologies that enable countries to establish high levels of domestic control over the energy supply chain.

Similarly, in terms of liquid fuels, even the most land-constrained nations can achieve a degree of self-sufficiency in advanced biofuel technologies [47,51]. Although, it is acknowledged that many critics question the capacity of existing or emergent biofuel technologies to adequately (socially, economically and ecologically) substitute for liquid fossil fuels at current levels of global demand, this is a moot point in the context of this discussion on enhancing energy security. The bottom line is that any level of domestically cultivatable liquid fuel (either fossil fuels or biofuel) enhances energy security. Although fossil fuel supplies cannot be cultivated, biofuel most certainly can.

5.2. Enhancing affordability

For fossil fuel technologies, both front-end and operational costs are significant. One recent study estimates the costs of coal-fired power plants is now in the neighbourhood of US$3500 per kW which means that a 600 MW coal plant costs approximately US$2 billion [52]. To compound the problem, fossil fuel costs are subject

[7] World Nuclear Association web-site accessed on April 4, 2011 at http://www.world-nuclear.org/info/inf75.html.

[8] Ibid.

to externally-influenced price fluctuations which trend upwards [35]. Conversely, the main costs associated with renewable energy technologies such as wind power and solar power arise at the capitalization stage and even these front-end costs have come down significantly. For example, Bolinger and Wiser [53] report that installed wind power project costs in the United States have declined from US$3500 per kW in 1985 to an average of US$2025 per kW in 2005. The added advantage of technologies such as wind and solar power is that once generation facilities are built, costs associated with energy production are both stable and nominal [47,54].

5.3. *Enhancing resilience*

Renewable energy enhances energy resilience in two significant ways. First, most renewable energy technologies are decentralized; and as such, reduce the impact arising from technological malfunctions or terrorist attacks which could seriously impair a nation's electricity grid. The loss of one wind power turbine or a cluster of wind power turbines is significantly less damaging to a power grid than the loss of one or two 1000 MW coal-fired power stations. If the four nuclear reactors that were damaged by the tsunami in Japan were instead replaced by a network of wind turbines spread across the northern island of Hokkaido, the damage to Japan's electricity infrastructure would have been negligible.

Second, renewable energy diverts oil profits which are now flowing to politically unstable nations to domestic enterprises, thereby diminishing financial support for terrorist groups and providing a source of jobs to domestic workers [39]. For example, a number of studies indicate that when compared to fossil fuel technologies on a per kilowatt hour basis, wind power provides far more job opportunities of a higher standard of employment and enhances the development of domestic industry [55–58].

6. Facilitating symbiosis

Given the advantages that many renewable energy technologies have over fossil fuel technologies in terms of delivering sustainable energy security, one is left to wonder how much longer fossil fuel interests can continue to defend the technological status quo.

Understandably, fossil fuel special interests will continue to defend their market positions for as long as possible and indications are that technological lock may be prolonged. There are trillions of dollars tied up in conventional energy infrastructure [15]. There are also financially entrenched supply chains, vociferous labor unions and both upstream (i.e. petroleum refining) and downstream (i.e. gasoline powered vehicle manufacturers) technological linkages that give rise to stringent opposition to change [20]. Moreover, there is a great deal of apathy within the general public to reducing carbon footprints. Whether this stems from a general unwillingness to trade off current economic gain for uncertain future economic pain [59,60], low prioritization of climate change as an issue of concern [61,62] or some other justification, public apathy enables politicians and policymakers to continue to reap the rewards from financial support provided by fossil fuel interests without paying a political price for ignoring environmental externalities. This essentially shifts the onus to renewable energy companies to proactively shape the industry's future because passive behavior at this juncture may mean a much larger role for nuclear power and fossil fuel/carbon capture and sequestration combinations than is prudent from a long-term energy security perspective.

The problem is that compared to fossil fuel (and nuclear power) firms, renewable energy companies are not well-endowed financially to shape political and public opinion. Furthermore, the leading renewable energy firms tend to stick to their respective renewable energy technology sectors (i.e. Vestas and Enercon in wind power; First Solar and Suntech in Solar PV) so these firms wind up competing across technological platforms in addition to trying to unseat the fossil fuel conglomerates. This significantly dilutes the potential to effectively counter spurious claims made by fossil fuel interests. The end result is that both policymakers and the general public are exposed to far greater perceptual influences from the fossil fuel lobby [20,63].

Until now, the dominant strategy has been for individual firms to collaborate within their respective technological sectors and lobby to influence policy through trade organizations such as the World Wind Energy Association and the European Solar Thermal Industry Federation. This results in renewable energy trade associations competing against each other in addition to competing against fossil fuel interests, significantly diluting potential impact. The renewable energy industry would benefit from a collaborative effort to form one or two truly transnational renewable energy associations that have a sole remit to unseat fossil fuel energy technologies as the dominant sources of energy. Although national renewable energy associations do exist in most countries, there is no transnational organization that currently has the financial might to counter fossil fuel lobby efforts. Once fossil fuel technologies are unseated from dominance, the renewable technologies could shift from collaborating to competing for the void left behind by fossil fuel technologies.

To be successful, renewable energy lobbyists need to counter misunderstandings that have been attributed to misinformation campaigns waged by the fossil fuel lobby [64]. Many policymakers still believe that the intermittent flows of energy associated with many renewable technologies (i.e. solar, wind, tidal etc.) render electricity networks to be unstable at any level of integration; despite current engineering consensus that up to 20% energy from stochastic sources can be incorporated into most existing electricity networks without any additional storage capacity or backup generators [7,54,65].

Many policymakers still believe that renewable energy technologies are simply insufficient to replace fossil fuel technology despite research which demonstrates how portfolios of renewable energy technologies can be combined to significantly reduce or completely replace fossil fuel energy [17,56,66].

Many policymakers still believe the exaggeration that industry will be unable to compete internationally if it is forced to utilize more costly renewable energy [20]. The validity of this claim is easily assessed. For the sake of analysis, ignore for the moment the data presented earlier that attests to the economic competitiveness of some forms of renewable energy (i.e. wind power, geothermal power) and instead assume that energy costs increase by 50% as result of a shift to an electricity generation profile consisting of more expensive renewable energy forms. Now consider the impact that this will have on an energy intensive industry that incurs 5% of operating costs on energy. The net impact on the bottom line for this energy intensive firm at a 40% income tax rate would be an increase in after-tax operating costs of a mere 1.5%. So, even for energy-intensive firms, the perception that international competitiveness will be undermined is not tenable, yet it persists.

Misinformation abounds in the global energy industry [5,64] and it is incumbent upon renewable energy firms to develop strategies to better inform both policy makers and the general public.

7. Conclusion

Although financially well-endowed entities support the fossil fuel energy sector, most individuals supporting the status quo are not immoral individuals bent on destroying our planet. Most are individuals who truly believe that the existing technological

paradigm governing energy provision is still the optimal solution given current levels of renewable energy technology development and global energy demand [20,67]. Most in the fossil fuel industry recognize the ecological perils presented by fossil fuel combustion; however, most would also argue that technological solutions exist to enable fossil fuel technologies to continue to benefit humanity without deviating from the economic underpinnings that have served humanity well over the past 200 years. In short, these individuals also suffer from misperceptions caused by their limited understanding of all available technologies. This is known as "bounded rationality" [68].

As this paper demonstrated, the short-comings associated with fossil fuel and the emergent benefits associated with renewable energy technologies indicate that conditions are increasingly conducive to a wide-sale transformation in how energy is generated. In fact, it is clear that a transition will eventually run its course. It may be accelerated by further fossil fuel cost escalations, renewable energy price decreases, clearer links between politically unstable oil regimes and terrorist financing, more certainty in regard to the economic and ecological impacts associated with climate change or even one or two more tragic oil spills such as that which occurred off the coast of Florida in the summer of 2010. Regardless of pace, eventually a transition will occur because if all other efforts to displace fossil fuels as the dominant sources for energy provision fail, eventually the exhaustion of fossil fuels will decide the matter [32,69].

Lamentably, for the flora and fauna that are at peril of extinction due to global warming [8,59] and the hordes of impoverished individuals who will suffer the brunt of the economic consequences associated with global warming, time is not an ally in regard to a transition to renewable energy. The transition needs to be expedited to abate the worst of the consequences [13] and it unfortunately comes down to the renewable energy firms to find new ways to collaborate and break the grip that the fossil fuel industry has on political power and public perception.

Fossil fuel is no longer in a symbiotic relationship with energy security; the relationship has become parasitic. Now, renewable energy is to energy security as the Egyptian plover is to the Nile crocodile. There is potential for a symbiotic relationship to exist but for that to happen, renewable energy firms must find a way of getting the crocodile to open its mouth.

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